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The Plasma Catecholamine Response to Ventricular Tachycardia Induction and External Countershock During Electrophysiologic Testing

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Adrenergic activation during electrophysiologic study could potentially alter the electrophysiologic properties of the arrhythmia substrate. However, the catecholamine response to ventricular tachycardia induction and termination during electrophysiologic testing has to date not been quantitated. Therefore, in 13 patients undergoing electrophysiologic study, arterial plasma norepinephrine and epinephrine were measured before, during and 1, 3, 5, 10 and 15 minutes after ventricular tachycardia induced by programmed stimulation and terminated by a single 100 J external countershock. Sinus rate and the effective refractory period at the right ventricular apex at a basic drive cycle length of 400 ms were measured after the countershock at the same time intervals used for the catecholamine measurements. The mean ventricular tachycardia cycle length (± SD) was 187 ± 30 ms, and the mean duration of ventricular tachycardia was 18 ± 4 seconds.

Plasma norepinephrine and epinephrine increased, respectively, from a baseline of 286 ± 141 and 119 ± 40 pg/ml to 770 ± 330 (169%) and 597 ± 467 pg/ml (402%), ($p < 0.01$) at 1 minute after the countershock. The mean plasma norepinephrine and epinephrine levels during ventricular tachycardia and at times greater than 1 minute after the shock did not differ significantly from baseline levels. Sinus rate increased from a baseline of 74 ± 13 to 103 ± 26/min (39%) at 1 minute after the shock ($p < 0.05$) and then returned to baseline. Right ventricular effective refractory period decreased from a baseline of 236 ± 27 to 212 ± 23 ms (−10%) and 226 ± 25 ms (−4%) at 1 and 3 minutes, respectively, after the countershock ($p < 0.01$), then returned to baseline. In some patients, a 10 to 20 ms decrease in effective refractory period persisted for up to 10 minutes. In an additional six patients without inducible ventricular tachycardia, plasma catecholamine levels did not change during programmed ventricular stimulation.

These data indicate that ventricular tachycardia induction and termination by a 100 J countershock result in a mean threefold increase in plasma norepinephrine level and a fivefold increase in plasma epinephrine level that are short-lived (< 3 minutes). This degree of adrenergic activation may be sufficient to significantly shorten ventricular refractoriness and potentially affect the results of subsequent attempts at programmed stimulation. During an electrophysiologic study, a rest period of 15 minutes after ventricular tachycardia termination by countershock should be adequate to avoid catecholamine-induced changes in electrophysiologic properties of the arrhythmia substrate.

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During electrophysiologic testing, programmed ventricular stimulation may result in the induction of rapid ventricular tachycardia which causes hemodynamic deterioration and requires direct current countershock to terminate. It is reasonable to expect that the induced ventricular tachycardia or external countershock, or both, may activate the sympathetic nervous system, with release of norepinephrine at adrenergic synapses and secretion of epinephrine from the adrenal medulla. However, no studies to date have examined the catecholamine response to ventricular tachycardia induction or external countershock during electrophysiologic testing.

Exogenous catecholamines such as isoproterenol decrease the ventricular effective refractory period and may

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facilitate the induction of ventricular tachycardia by programmed ventricular stimulation (1–3). It is therefore possible that endogenous catecholamines released as a response to ventricular tachycardia induction or external countershock could alter the electrophysiologic properties of the underlying arrhythmia substrate and affect the results of subsequent programmed stimulation. The extent and duration of these possible effects have to date not been investigated.

The purpose of this study was to quantitate the response of arterial plasma norepinephrine and epinephrine to ventricular tachycardia induction and termination by external countershock during electrophysiologic testing. Serial ventricular effective refractory period measurements after the direct current countershock were used as an indicator of the potential extent and duration of the electrophysiologic effects of the released catecholamines on ventricular myocardium.

Methods

Patient characteristics. The subjects of this study were 13 consecutive patients not being treated with a beta-adrenergic blocking agent who underwent an electrophysiologic study in which ventricular tachycardia requiring a single direct current countershock for termination was induced. The clinical features of these patients are described in Table 1. The clinical indication for the electrophysiologic study was a recent episode of aborted sudden death in six patients, unexplained syncope in five patients and a history of sustained ventricular tachycardia in two patients. There were eight women and five men, with a mean age (± 1 SD) of 52 ± 19 years. Seven patients had coronary artery disease and a history of myocardial infarction, three had hypertrophic cardiomyopathy, one had idiopathic dilated cardiomyopathy and two had no identifiable structural heart disease. Congestive heart failure was present in six patients who had a mean left ventricular ejection fraction of 0.24 ± 0.07 (range 0.15 to 0.30) as determined by contrast or radionuclide ventriculography. The seven patients who did not have congestive heart failure had a mean ejection fraction of 0.63 ± 0.14 (range 0.44 to 0.82).

Control patients without inducible tachycardia. The catecholamine response to programmed ventricular stimulation itself was determined in six additional patients who underwent electrophysiologic study and did not have inducible ventricular tachycardia. The clinical features of these patients are described in Table 2. There were four men and two women, with a mean age of 46 ± 18 years. Three patients underwent electrophysiologic study for evaluation of unexplained syncope, two because of a recent episode of aborted sudden death and one because of a history of sustained ventricular tachycardia. Three patients had coronary artery disease and a history of myocardial infarction, one had idiopathic dilated cardiomyopathy and two had no identifiable structural heart disease. Congestive heart failure was present in three patients who had a mean left ventricular ejection fraction of 0.30 ± 0.06. The three patients without congestive heart failure had a mean ejection fraction of 0.5 ± 0.16.

Drug therapy at the time of electrophysiologic study is described in Tables 1 and 2; nitrate therapy was discontinued on the day of the study. Patients who had been treated with a beta-adrenergic blocking agent within 1 month of the electrophysiologic study were not included. All patients provided informed consent to participate in this study under a

Table 1. Clinical Features of 13 Patients Studied and Characteristics of Ventricular Tachycardia Induced by Programmed Stimulation

						Induced VT	
Case	Age (yr) & Sex	Heart Disease	CHF	Drugs	LVEF	CL (ms)	Duration (seconds)
1	51M	CAD	Yes	D	0.30	200	25
2	62M	CAD	Yes	None	0.26	190	15
3	28F	None	No	None	0.60	160	22
4	63F	CAD	Yes	D,Fu	0.30	180	18
5	62M	CAD	No	Nifedipine	0.44	170	21
6	73M	CAD	Yes	D,Fu	0.14	280	22
7	33F	IDC	Yes	D,Fu,C	0.26	170	18
8	71M	CAD	No	Diltiazem	0.50	180	10
9	22F	HCM	No	None	0.80	170	19
10	66F	CAD	Yes	D,Fu,C	0.15	180	16
11	52F	HCM	No	None	0.65	170	12
12	52F	HCM	No	None	0.65	170	16
13	67F	None	No	None	0.58	200	18
Mean	52				0.45	187	18
± SD	19				0.23	30	4

C = captopril; CAD = coronary artery disease; CHF = congestive heart failure; CL = cycle length; D = digoxin; F = female; Fu = furosemide; HCM = hypertrophic cardiomyopathy; IDC = idiopathic dilated cardiomyopathy; LVEF = left ventricular ejection fraction; M = male; VT = ventricular tachycardia.

Table 2. Clinical Features and Plasma Catecholamine Levels During Programmed Ventricular Stimulation in Six Patients Without Inducible Ventricular Tachycardia

Case	Age (yr) & Sex	Heart Disease	CHF	Drugs	LVEF	Plasma Catecholamine Level (pg/ml)					
						Baseline		After S_2 and S_3*		After S_4*	
						NE	E	NE	E	NE	E
14	39F	IDC	Yes	D,Fu,C	0.24	308	273	314	100	326	123
15	71M	CAD	No	None	0.32	379	159	341	137	376	147
16	31M	None	No	None	0.58	118	161	152	138	113	121
17	50M	CAD	Yes	D,Fu	0.30	168	169	193	60	197	68
18	64F	CAD	Yes	D,Fu	0.36	145	122	122	142	96	109
19	24M	None	No	None	0.60	517	126	567	115	549	114
Mean	46				0.40	272	168	281†	115†	276†	114†
± SD	18				0.15	157	55	165	32	174	25

*At two right ventricular sites and two basic drive cycle lengths (600 or 500 ms and 400 ms). †$p > 0.05$ versus baseline. E = epinephrine; NE = norepinephrine; S_2 = single extrastimulus; S_3 = double extrastimuli; S_4 = triple extrastimuli; other abbreviations as in Table 1.

protocol approved by the Institutional Review Board at the University of Michigan.

Electrophysiologic study protocol. The electrophysiologic study was performed with patients in the fasting state, at least four half-lives after discontinuation of all antiarrhythmic drugs. No patient was premedicated with a sedative or received a sedative during the course of the electrophysiologic study. Two quadripolar electrode catheters were inserted percutaneously into a femoral vein and positioned against the right ventricular apex and outflow tract. A short cannula was inserted into a femoral artery for obtaining blood samples and for continuous monitoring of the blood pressure. Electrocardiographic leads V_1, I and III and the intracardiac electrograms recorded at the right ventricular apex and outflow tract were displayed on an oscilloscope and recorded at a paper speed of 25 mm/s with an Electronics for Medicine VR-16 recorder. Programmed stimulation was performed with a programmable stimulator (Bloom Associates) using stimuli 2 ms in duration and twice diastolic threshold in intensity.

Sustained ventricular tachycardia was defined as ventricular tachycardia greater than 30 seconds in duration or requiring countershock for termination. Nonsustained ventricular tachycardia was defined as ventricular tachycardia six complexes to 30 seconds in duration.

Programmed ventricular stimulation protocol. Using six to eight beat basic drive trains at two different cycle lengths (600 or 500 ms and 400 ms), programmed stimulation was performed with a single extrastimulus and then with double extrastimuli, first at the right ventricular apex, then at the outflow tract. Programmed stimulation was then performed with triple extrastimuli at the apex, then at the outflow tract. The coupling intervals between extrastimuli were changed in 10 ms decrements. The intertrain interval was 3 to 4 seconds.

The end point for the stimulation protocol was the induction of sustained ventricular tachycardia requiring a single 100 J direct current countershock for termination. On induction of sustained ventricular tachycardia, the patient's level of consciousness was monitored, and the countershock was delivered as soon as the patient became unresponsive to verbal stimuli.

Before induction of the sustained ventricular tachycardia that required countershock, nonsustained ventricular tachycardia more than 3 seconds in duration or sustained ventricular tachycardia not requiring direct current countershock was not induced in any patient. If more than a single 100 J countershock was required to terminate the ventricular tachycardia, the patient was not included in this study.

Catecholamine determinations. Two baseline samples of blood (2.5 cc each) from the femoral artery were obtained 5 minutes apart after a 15 minute rest period following placement of the electrode catheters within the right ventricle. If ventricular tachycardia was not induced by programmed stimulation with single or double extrastimuli, a blood sample was obtained immediately after completion of stimulation with double extrastimuli. On induction of sustained ventricular tachycardia, an attempt was made to obtain a blood sample before countershock. This was feasible in 10 patients in whom a blood sample was obtained between 8 and 15 seconds after the onset of ventricular tachycardia. Blood samples were then obtained at 1, 3, 5, 10 and 15 minutes after the countershock was delivered.

In the six patients who did not have inducible ventricular tachycardia, a blood sample was obtained immediately on completion of stimulation with double extrastimuli and again on completion of the entire stimulation protocol. The duration of the stimulation protocol was 20 to 25 minutes.

Plasma norepinephrine and epinephrine were measured using a single isotope radioenzymatic assay (4). All samples from a given patient were analyzed in the same assay.

Determination of sinus rate, arterial pressure and ventricular effective refractory period. The sinus rate and mean arterial pressure were determined from a 10 second

sample of sinus rhythm at 1, 3, 5, 10 and 15 minutes after the countershock. This was not possible in two patients who developed atrial fibrillation or flutter after the countershock.

In nine patients the effective refractory period at the right ventricular apex was determined at 1, 3, 5, 10 and 15 minutes after ventricular tachycardia termination by countershock. The effective refractory period was determined using a basic drive cycle length of 400 ms. In none of these nine patients was the electrode catheter at the right ventricular apex repositioned in the course of this study. If the electrode catheter became displaced, as evidenced by a marked increase in pacing threshold and a change in fluoroscopic position, the patient was excluded from the study.

Statistical analysis. The plasma norepinephrine and epinephrine levels, sinus rate, arterial pressure and ventricular effective refractory periods after external countershock were compared statistically with corresponding baseline values by analysis of variance for repeated measures using Dunnett's multiple comparison procedure (5). A paired t test demonstrated no significant difference between the two baseline norepinephrine and epinephrine levels, and therefore the average of the two baseline levels was used in the analysis of variance. Baseline catecholamine levels in patients with and without congestive heart failure were compared by Student's t test. Correlation coefficients were obtained by linear regression analysis.

Results

Induced ventricular tachycardia. The mean cycle length of the induced ventricular tachycardia was 187 ± 30 ms. The induced tachycardia was unimorphic in 2 patients and polymorphic in 11 patients. It was induced by a single extrastimulus in 1 patient, double extrastimuli in 2 patients and triple extrastimuli in 10 patients. The tachycardia was induced by stimulation at the right ventricular apex in 11 patients and at the outflow tract in 2 patients.

In each patient, the mean arterial blood pressure fell to a level of 35 mm Hg or less within 10 seconds after the initiation of ventricular tachycardia. The mean duration of the tachycardia before termination by external countershock was 18 ± 4 seconds (range 10 to 25) (Table 1).

Baseline plasma catecholamine levels. The mean baseline norepinephrine and epinephrine levels among the 19 patients in this study were 276 ± 141 and 134 ± 50 pg/ml, respectively. There was no significant difference in the baseline norepinephrine and epinephrine levels between the 9 patients who had congestive heart failure (246 ± 114 and 129 ± 66 pg/ml, respectively), and the 10 patients without congestive heart failure (303 ± 162 and 140 ± 32 pg/ml, respectively) ($p > 0.05$). Similarly, there was no difference in these levels between the 10 patients who were being treated with digoxin, furosemide, captopril, nifedipine or diltiazem and the 9 patients who were not. There was no significant correlation between left ventricular ejection fraction and the baseline norepinephrine or epinephrine levels.

Plasma catecholamines in patients without inducible ventricular tachycardia. The mean baseline norepinephrine and epinephrine levels were 272 ± 157 and 168 ± 55 pg/ml, respectively, in the six patients without inducible ventricular tachycardia (Table 2). There was no significant change in these levels after programmed stimulation with one and two extrastimuli, or after programmed stimulation with three extrastimuli.

Plasma catecholamines in patients with inducible ventricular tachycardia. The mean baseline norepinephrine and epinephrine levels in the 13 patients who had inducible venticular tachycardia were 286 ± 141 and 119 ± 40 pg/ml, respectively. In the nine patients in whom ventricular tachycardia was induced by programmed stimulation with triple extrastimuli, there was no change from baseline in the norepinephrine or epinephrine level after completion of programmed stimulation with one or two extrastimuli.

After the induction of ventricular tachycardia, but before the external countershock, the plasma norepinephrine level increased by at least twofold in three patients (Cases 8 to 10); in two of these three patients, the plasma epinephrine level also increased at least twofold. However, among the other 10 patients whose catecholamine levels were measured during ventricular tachycardia before the countershock, there was no significant increase in the mean plasma norepinephrine or epinephrine level (Fig. 1, Table 3).

The mean norepinephrine and epinephrine levels were consistently greater than baseline at 1 minute after the external countershock ($p < 0.01$) (Fig. 1, Table 3). Overall, there was approximately a threefold increase in the mean norepinephrine level and a fivefold increase in the mean epinephrine level. Both norepinephrine and epinephrine levels then fell rapidly and were not significantly greater than baseline at 3, 5, 10 or 15 minutes after the external countershock. There was not a direct correlation between the duration of ventricular tachycardia and the plasma norepinephrine or epinephrine level during ventricular tachycardia or at 1 minute after countershock.

Changes in arterial pressure. The mean arterial pressure was 90 ± 12 mm Hg at baseline, and it fell to 28 ± 4 mm Hg ($p < 0.01$) during ventricular tachycardia. It increased significantly over baseline after the countershock (to 110 ± 18 mm Hg at 1 minute [$p < 0.01$], 100 ± 15 mm Hg at 3 minutes [$p < 0.01$] and 97 ± 15 mm Hg at 5 minutes [$p < 0.05$]) and then returned to baseline.

Changes in sinus rate and ventricular refractoriness. The baseline sinus rate was 74 ± 13/min. There was a significant increase to 103 ± 26/min at 1 minute after the external shock ($p < 0.05$) (Fig. 2). The mean sinus rate at subsequent time intervals after the external countershock was not significantly different from baseline.

The mean baseline right ventricular effective refractory

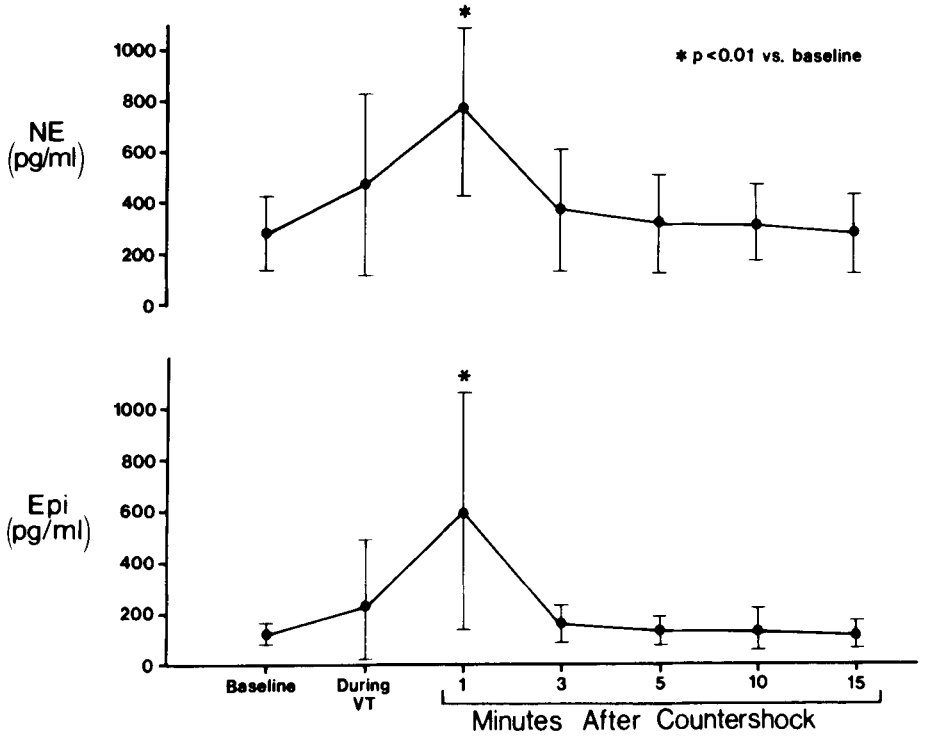

Figure 1. Plasma epinephrine (Epi) and norepinephrine (NE) levels (mean ± 1 SD) during induced ventricular tachycardia (VT) and after a 100 J countershock. Probability (p) values refer to comparison with baseline.

period was 236 ± 27 ms. There was a significant decrease from baseline at 1 and 3 minutes after the external countershock (to 212 ± 23 and 226 ± 25 ms, respectively [$p < 0.01$] [Fig. 2, Table 4]). At subsequent time intervals after external countershock, it did not differ from baseline; however, in some patients a 10 to 20 ms decrease in the ventricular effective refractory period persisted for up to 10 minutes (Table 4).

Correlations between catecholamine levels and sinus rate or ventricular refractoriness. There was not a significant correlation in the baseline state between the norepinephrine or epinephrine level and the sinus rate or the ventricular effective refractory period. At 1 minute after external countershock, when the norepinephrine and epinephrine levels were at their highest, there was not a significant correlation between these levels and the sinus rate

Table 3. Plasma Catecholamine Response to Ventricular Tachycardia Induction and Termination by External Countershock in 13 Patients

	Baseline (pg/ml)		During VT, Before Shock (pg/ml)		After One 100 J Countershock (pg/ml)									
					1 Minute		3 Minutes		5 Minutes		10 Minutes		15 Minutes	
Case	NE	E	NE	E	NE	E	NE	E	NE	E	NE	E	NE	E
1	248	94	ND	ND	593	299	229	83	240	94	246	105	228	94
2	270	55	411	44	645	222	344	74	372	54	344	36	314	43
3	328	204	433	102	868	608	501	185	366	91	344	173	503	187
4	99	104	93	106	325	302	150	95	90	66	90	66	61	36
5	154	129	191	117	448	485	223	168	121	129	117	140	113	134
6	230	76	ND	ND	469	184	151	55	261	86	184	73	184	81
7	257	100	255	102	638	906	398	296	319	179	350	154	358	182
8	443	137	1,208	975	1,227	518	722	238	573	181	489	163	458	148
9	216	146	455	651	975	1,292	219	191	230	238	233	277	219	115
10	494	166	950	198	869	399	711	183	568	123	543	149	388	146
11	194	100	ND	ND	1,372	1,781	282	273	257	154	256	120	236	128
12	133	145	139	92	392	384	142	110	119	129	109	76	103	110
13	548	91	601	65	1,053	385	767	142	673	107	643	295	532	68
Mean	286	119	474†	245†	760*	597*	372†	161†	322†	125†	304†	140†	284†	113†
± SD	141	40	361	311	330	467	230	77	185	52	172	77	155	48

*$p < 0.01$ versus baseline; †$p > 0.05$ versus baseline. ND = not determined; other abbreviations as in Tables 1 and 2.

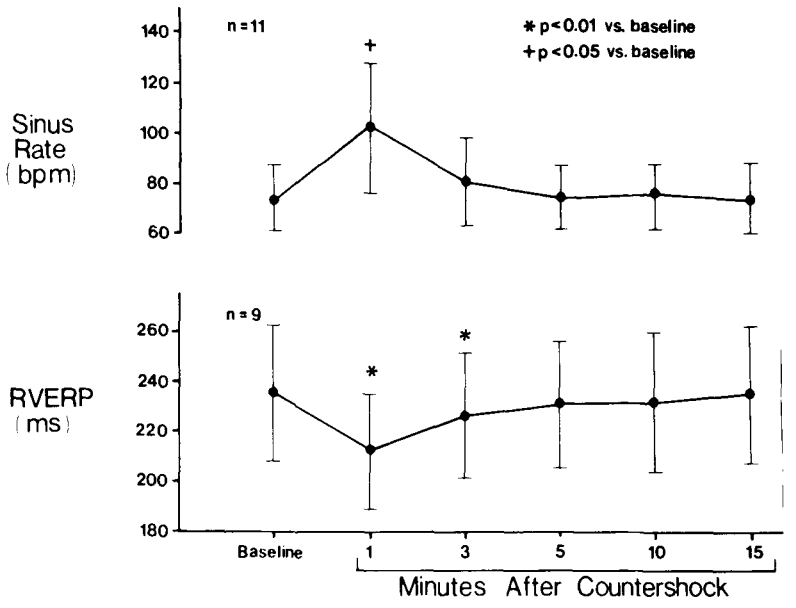

Figure 2. Sinus rate and right ventricular effective refractory period (RVERP) after termination of ventricular tachycardia by a 100 J countershock. Shown are mean values ± 1 SD. Probability (p) values refer to comparison with baseline.

or ventricular effective refractory period. There was also not a significant correlation between the change in norepinephrine or epinephrine level from baseline to 1 minute after external countershock and the corresponding change in sinus rate or ventricular effective refractory period, when these values were expressed either in absolute terms or as percent change.

Discussion

Catecholamine response. No prior studies have quantitated the catecholamine response to ventricular tachycardia induction or termination during electrophysiologic testing. The results of the present study demonstrate that, after the induction of rapid ventricular tachycardia that results in loss of consciousness and which is terminated by a single 100 J external countershock, 1 minute later there is approximately a threefold increase in the mean arterial plasma norepinephrine level and approximately a fivefold increase in the mean epinephrine level. These plasma catecholamine levels are comparable with levels achieved during moderately severe exercise (6). The increase in plasma catecholamines after countershock is short-lived, and by 3 minutes after the external countershock the mean norepinephrine and epinephrine levels are no longer significantly greater than baseline values.

Changes in ventricular refractoriness. In association with the marked but brief increase in norepinephrine and epinephrine levels, there was a 10 to 40 ms decrease in the right ventricular effective refractory period. The temporal association between the increase in plasma catecholamines and the decrease in ventricular refractoriness suggests that the latter was caused by adrenergic activation. When achieved by infusion of epinephrine, plasma epinephrine levels in the same range observed in response to countershock are as-

Table 4. Changes in the Right Ventricular Effective Refractory Period (at a basic drive cycle length of 400 ms) After External Countershock in Nine Patients

Case	Baseline ERP (ms)	ERP After Countershock (ms)				
		1 Minute	3 Minutes	5 Minutes	10 Minutes	15 Minutes
5	230	190	220	230	230	230
6	290	260	280	280	290	290
7	190	180	190	190	190	190
8	230	220	230	230	230	240
9	250	220	220	240	240	250
10	230	220	230	230	230	230
11	230	200	210	210	210	220
12	250	220	240	250	250	250
13	220	200	210	220	220	220
Mean	236	212*	226*	231†	232†	236†
± SD	27	23	25	25	28	27

*$p < 0.01$ versus baseline; †$p > 0.05$ versus baseline. ERP = effective refractory period.

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sociated with significant cardiovascular effects (6). Furthermore, changes in the right ventricular effective refractory period comparable with the changes observed in the present study have been reported to occur after administration of isoproterenol in doses sufficient to facilitate the induction of ventricular tachycardia during electrophysiologic testing (2,3).

Whereas the increase in the mean catecholamine levels and the mean sinus rate lasted only 1 minute after the countershock, the decrease in the mean ventricular effective refractory period persisted for 3 minutes and in some patients it did not return to baseline values until 15 minutes after the countershock. This suggests that the effect of catecholamines on the effective refractory period may lag behind changes in the plasma catecholamine levels and sinus rate. The observation that mean arterial pressure remained significantly elevated for 5 minutes after the countershock provides additional evidence that the cardiovascular effects of adrenergic activation may persist for several minutes. These findings indicate that when rapid ventricular tachycardia requiring direct current countershock is induced during an electrophysiologic study, a rest period of 15 minutes is advisable to avoid catecholamine-induced changes in electrophysiologic properties that could potentially affect the results of subsequent attempts at programmed ventricular stimulation.

Effects of programmed stimulation. Because catecholamine levels did not increase during the course of programmed ventricular stimulation in the six patients who did not have inducible ventricular tachycardia, the increase in norepinephrine and epinephrine that occurred in the patients who had inducible ventricular tachycardia cannot be attributed to the effects of programmed ventricular stimulation. Although no other studies have investigated the catecholamine response to programmed ventricular stimulation, Schwartz et al. (7) measured the catecholamine response to sustained atrial pacing and also found no change in arterial catecholamine levels.

Cathecholamine response to ventricular tachycardia. It is unclear whether the increase in catecholamines was caused primarily by the ventricular tachycardia or by the 100 J countershock used to terminate the ventricular tachycardia. Although the blood pressure during ventricular tachycardia fell to a very low level in all patients, in most patients an appreciable rise in norepinephrine and epinephrine levels was not detected before the external countershock. However, because of the short interval between the onset of ventricular tachycardia and the time of blood sampling, and because of the severe circulatory stasis that presumably was present before termination of the ventricular tachycardia by countershock, the absence of a detectable rise in the arterial plasma norepinephrine and epinephrine levels does not necessarily rule out a catecholamine response to ventricular tachycardia.

At 1 minute after the external countershock, when the maximal changes in catecholamine levels and ventricular effective refractory periods were detected, there was no correlation between the magnitude of the increase in catecholamines and the decrease in ventricular refractoriness. It may be that plasma norepinephrine and epinephrine levels do not accurately reflect myocardial catecholamine concentrations. Alternatively, it may be that there is not a linear relation between catecholamine levels and the ventricular effective refractory period.

Interpatient variability in catecholamine levels. There was considerable interpatient variability in the baseline arterial plasma norepinephrine concentration. Factors that may have contributed to this variability include the presence of congestive heart failure in some patients, variability in anxiety levels, the time of day that the study was performed, the state of sodium balance and the extent of physical training (8–10).

Limitations. A limitation of this study is that, because only a small proportion of norepinephrine released into the synaptic cleft spills over into the general circulation, the concentration of norepinephrine measured in arterial plasma may have been grossly less than the concentration at its site of action at the adrenergic synapse. A second limitation of this study is that the direct effects of the catecholamine response to ventricular tachycardia induction and termination on subsequent attempts at induction were not investigated. A second induction of ventricular tachycardia shortly after the first induction would have most likely necessitated a second external countershock, and also would not have allowed determination of the time course of changes in catecholamines and refractory periods after the first ventricular tachycardia induction and termination.

Conclusions. The validity of programmed ventricular stimulation and electropharmacologic testing in patients with inducible ventricular tachycardia depends on stability in the electrophysiologic properties of the arrhythmia substrate and the ability to reproducibly induce a given form of ventricular tachycardia. The results of this study suggest that the testing process itself, that is, the induction of ventricular tachycardia and its termination by external countershock, results in significant adrenergic activation and shortening of the ventricular effective refractory period, factors that could potentially affect the results of subsequent programmed stimulation. However, even with increases in norepinephrine and epinephrine as great as 7-fold and 18-fold, respectively, the duration of the catecholamine response is brief, with the plasma catecholamine levels and the effective refractory period returning to baseline within 15 minutes. These findings suggest that a 15 minute rest period after ventricular tachycardia induction and termination by a 100 J countershock should be adequate to avoid catecholamine-induced changes in electrophysiologic properties of the arrhythmia substrate.

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